INNOVATIVE TECHNOLOGY
Summary Report

Concrete Spaller

Deactivation and Decommissioning
Focus Area

Prepared for
U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology

December 1998

INNOVATIVE TECHNOLOGY
Summary Report

Concrete Spaller

OST Reference #2152

Deactivation and Decommissioning
Focus Area

Demonstrated at
Hanford Site
Richland, Washington

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://OST.em.doe.gov under "Publications."

TABLE OF CONTENTS

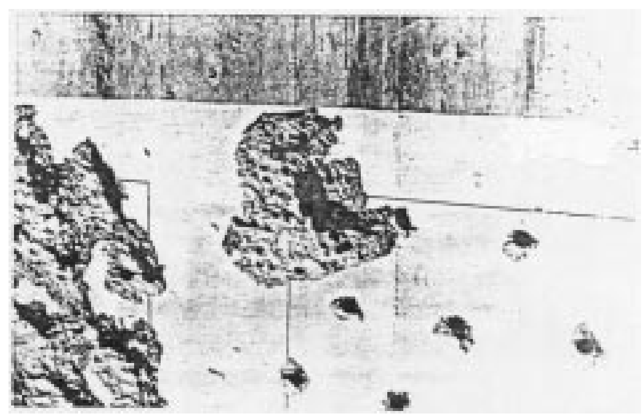
SECTION 1

SUMMARY

Pacific Northwest National Laboratory's concrete spaller is a hand-held tool that can be used for decontaminating flat or slightly curved concrete surfaces, obtaining concrete samples, and in-depth removal from cracks in concrete. The concrete spaller includes a 9-ton hydraulic cylinder and spalling bit. It runs from a hydraulic pump that expands the spaller in pre-drilled holes in the concrete. The result is removal of concrete chunks that fall into the attached metal shroud. The concrete spaller is more efficient than traditional tools such as hand-held pneumatic scabblers and scalers. For example, the spaller is capable of spalling 1.3 m^3/hr (0.23 ft^2/min), compared to 1.1 m^2/hr (0.20 ft^2/min), for the baseline scabbler and scaler demonstrated at 3-mm (1/8-in.) depth. The spaller is also capable of removing concrete at a greater depth than traditional tools. Operating cost of the spaller (\$128/m^2 or \$11.93/ft^2 [optimum conditions]) is less than the baseline tools: scaler (\$155/m^2 or \$14.40/ft^2) and scabbler (\$156/m^2 or \$14.53/ft^2).

■ Technology Summary

The concrete spaller is a hand-held concrete surface removal tool developed by Pacific Northwest National Laboratory (PNNL). The spaller includes a 9-ton hydraulic cylinder and a patented spalling bit and is operated manually with a 6.9 x 10^4-kPa (10,000-psi) hydraulic pump [see Figure 1.] The spaller removes concrete surfaces in pieces ranging from 18 to 41 cm (7 to 16 in.) in average diameter. The concrete spaller is operated by drilling holes in the concrete in a honeycomb pattern, then inserting the spaller bit and opening a hydraulic valve. Upon opening the valve, the bit expands almost immediately and the spalling occurs; a chunk of concrete, up to 5 cm (2 in.) thick, falls into a metal shroud attached around the spaller [see Figure 2.]



The unit is suitable for flat (or slightly curved) concrete walls and floors. It can be used on contaminated surfaces because it has a detachable shroud that has a vacuum port for control of any airborne materials. A vacuum high-efficiency particulate air (HEPA) filtration unit can be connected by hose to the shroud vacuum port.

Problem Addressed

The U.S. Department of Energy (DOE) has numerous buildings and facilities that have become contaminated through operation of nuclear reactors, fuel fabrication processes, and research laboratory operations. These buildings and facilities, often constructed of concrete, need to be decontaminated before they can be safely decommissioned or demolished. The concrete spaller provides an attractive alternative to traditional methods of decontaminating concrete surfaces using scabbling, scaling, or grinding techniques. The spaller removes concrete to a greater depth than do traditional tools. This is particularly beneficial for use on cracked concrete surfaces where contamination may have penetrated beyond the surfaces that could be efficiently removed through scabbling, scaling, or grinding. For decontamination and decommissioning (D&D) projects, the concrete spaller can be used for radiologically decontaminating large areas or hot spots, obtaining samples of concrete, and for removing in-depth contamination from cracks in concrete.

Potential Markets/Applicability

The concrete spaller system can best be used for decontaminating surfaces and cracks or taking samples from concrete slabs, floors, and walls. Potential applications at old reactors undergoing D&D include walls and floors in tunnels, fuel storage basins, and other facilities that have involved nuclear fuels.

Advantages of the Improved Technology

Some of the advantages and shortfalls of the concrete spaller are identified below. Additionally, the improved technology is compared against baseline tools in the tables below, with production rates shown for removing 3 mm (1/8 in.) of concrete surface.

- Thoroughly decontaminates surfaces with very little dust production
- Removes material efficiently to a greater depth than baseline tools
- Less vibration for the operator compared to baseline tools
- Hand-held and portable; but without a sling to carry its weight, the operation is tiring
- Increased performance factor of 17% compared to scaler or scabbler
- Spalling was 40% slower than diamond grinding up to depths of 3 mm (1/8 in.)
- Spalling leaves a much more uneven surface than other tools
- Spalling would be an extremely effective method for removing deep contamination in cracks and for taking concrete samples.

Category	Comments
Cost	Under optimum conditions, operating costs for the spaller would be 15% lower than the baseline scabbler and scaler. However, operating costs for the spaller were 22% higher than the baseline tools during the demonstration.
Operation and Ease of Use	The concrete spaller is easy to operate and has less vibration than the scabbler and scaler baseline tools. The spaller is heavier and slower than a diamond grinder for depths to approximately 3 mm, but removes concrete to greater depths faster.
Implementation	No special site services are required to implement the concrete spaller or the baseline tools.
Secondary Waste Generation	The concrete spaller generated very little concrete dust, but produces chunks of waste (contaminated concrete). Dust from pre-drilling holes must be controlled.
As low as Reasonably Achievable (ALARA)	Use of the concrete spaller results in comparable exposure time, but lower airborne contamination than the baseline technologies.
Performance	Decontaminates 1.3 m^2/hr (13.6 ft^2/hr) by removing surfaces to depths over 3 mm (1/8 in.).

Cost Element	Improved				Baseline - Scaler				Baseline - Scabbler			
	Production Rate		Unit Cost		Production Rate		Unit Cost		Production Rate		Unit Cost	
	m^2/hr	(ft^2/hr)	\$/m^2	(\$/ft^2)	m^2/hr	(ft^2/hr)	\$/m^2	(\$/ft^2)	m^2/hr	(ft^2/hr)	\$/m^2	(\$/ft^2)
Drill Holes*	1.64	(17.6)	99	(9.22)	N/A		N/A		N/A		N/A	
Decontaminate Wall*	5.57	(60.0)	29	(2.71)	N/A		N/A		N/A		N/A	
Total Unit Costs*			128	(11.93)			155	(14.4)			156	(14.5)

* Optimum conditions (field work)

Operator Concerns

When being used with a vacuum filtration system, users must be vigilant to ensure that the vacuum hose stays connected properly and that a suitable level of vacuum is maintained to ensure that airborne releases do not occur. The concrete spaller uses high-pressure hydraulic oil, which could present a hazard if the spaller is held by the hydraulic fittings while it is being used. This is a natural grip if no handle extension is provided on the tool. A handle extension can easily be fabricated from stainless-steel pipe, aluminum, or plastic.

Skills and Training

Training of field technicians is minimal.

■ Demonstration Summary

The concrete spaller was demonstrated January 16 through January 27, 1998.

Demonstration Site Description

The capabilities of the concrete spaller were demonstrated for the DOE at the C Reactor Interim Safe Storage (ISS) Project as part of the Large-Scale Demonstration and Deployment Project (LSDDP) at the DOE's Hanford Site in Richland, Washington. The demonstration consisted of decontaminating two areas on the exhaust fan room wall to free-release levels. The wall surfaces were contaminated with beta/gamma radioactivity. Spalling was accomplished with a hydraulically energized spalling bit inserted in predrilled 2.5-cm (1-in.)-diameter holes. During the drilling, a small stream of water was sprayed on the wall to control the spread of contamination. With each spall, the spaller removed 3 mm (1/8 in.) depth or more of concrete. Pre-drilling took the most time; however, faster drills are available.

Regulatory Issues

There are no regulatory issues or permits required for using the concrete spaller.

Technology Availability

- The concrete spaller, which has been patented by PNNL, is in the prototype stage. The bit and some other components are not currently commercially available. However, these parts can be produced in any well-equipped machine shop. The hydraulic pump and cylinder are commercially available, and both have been in production for at least 15 years.

- The first demonstration of the concrete spaller technology on contaminated surfaces was at the C Reactor fan room wall at DOE's Hanford Site near Richland, Washington. The tool had been previously tested on an uncontaminated building wall in the F Reactor area at the Hanford Site and was tested at a contaminated hot cell at PNNL.

Technology Limitations/Needs for Future Development

- A long-lasting lubricant and/or an automatic lubrication device would make spaller operation more convenient.
- A simplified spalling bit design, or some other manufacturing technique, would reduce the cost of this expendable part.
- A lighter handle and/or a longer extension would make the tool easier to use and would reduce operator fatigue.
- In the early 1980s, a similar tool was tested on an uncontaminated wall, using a semi-automatic drilling system mounted on a forklift truck. Given the advances in robotic technology over the last 18 years, an automatic drilling system should be used when a large surface requires decontamination.
- Fitting the drill with an automatic water spray nozzle or a vacuum shroud (connected to a HEPA filtration system) would enable one worker to perform the drilling safely.

■ Contacts

Management
John Duda, FETC, (304) 285-4217
Glenn Richardson, DOE-RL, (509) 373-9629
Shannon Saget, DOE-RL, (509) 372-4029

Technical Information
Stephen Pulsford, BHI, (509) 375-4640
Mark R. Mitchell, PNNL, (509) 372-4069
Gregory Gervais, USACE, (206) 764-6837

Licensing
James H. Jarett, PNNL, (509) 372-4347

Other
All published Innovative Technology Summary Reports are available at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 web site, provides information about Office of Science and Technology (OST) programs, technologies, and problems. The OST reference number for the Concrete Spaller is 2152.

SECTION 2

TECHNOLOGY DESCRIPTION

■ Overall Process Definition

The DOE nuclear facility D&D program requires decontamination techniques suitable for flat or slightly curved surfaces as a part of D&D projects. The improved tool that was demonstrated can be used for radiological decontamination of large areas or hot spots for floors and walls, prior to final or release radiological surveys. The demonstration was performed to decontaminate (to free-release levels) parts of the exhaust fan room wall, which is located in the C Reactor building's southeast work area.

The system consists of the concrete spaller and hydraulic pump shown in Figure 1 (in Section 1) and in Figure 3 below.

Components

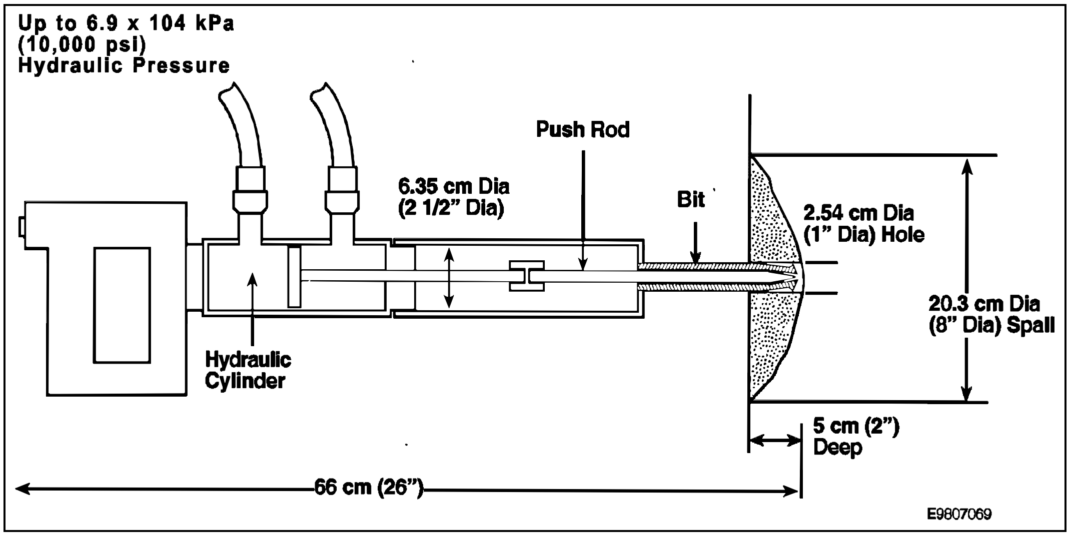
The concrete spaller weighs approximately 13.6 kg (30 lb) and consists of the following components:

1. Patented spalling bit with an internal-tapered sliding push rod, all made from hardened steel
2. Removable sheetmetal shroud for dust and fragment control with a viewing window and a vacuum port
3. Hydraulic cylinder rated at 9 tons
4. Handle extension for hydraulic cylinder
5. Hoses to connect the pump and cylinder
6. Electric/hydraulic pump.

Features

The hydraulic pump used was a 19.5-amp, 110-volt unit weighing 50 kg (108 lb), manufactured by Everpac Company (Butler, Wisconsin), and rated at 6.9×10^4 kpa (10,000 psi). The hydraulic system includes a manual four-way valve that controls advancing or retracting the hydraulic piston. The tapered push rod is connected to the hydraulic piston rod with a screwed coupling and expands the bit as it advances through an opening in the end of the bit. The rod pushes against the bottom of a pre-drilled hole, causing the bit to back out of the hole somewhat as the bit expands.

Figure 4 shows the spaller details without the removable handle extension. Figure 5 shows the push rod extended through the bit.



The retreating expanding bit causes spalls (chunks) to fall off the concrete surfaces in irregular shapes ranging 18 to 41 cm (7 to 16 in.) in average diameter and up to 5 cm (2 in.) thick. With the holes spaced approximately 20 cm (8 in.) apart, the depth of concrete surface removal ranges from 3 mm (1/8 in.) to 5 cm (2 in.). By placing the pre-drilled holes closer together, the minimum depth of concrete surface removed can be increased.

Overview

- The concrete spaller is a hand-held concrete and coating removal tool that includes a patented spalling bit, hydraulic cylinder, and electric hydraulic pump suitable for flat (or slightly curved) walls and floors.

- Pilot holes are pre-drilled in the concrete for receiving the spaller bit.

- Average depth of spalling is related to pilot hole spacing. The spaller is best suited for removing concrete depths of 3 mm (1/8 in.) or greater. A maximum depth of 5 cm (2 in.) should be observed to limit bit breakage. For most applications, the inventor recommends 5-cm (2-in.)-deep holes, drilled on 20-cm (8-in.) centers, in a triangular or honeycomb pattern. A hole diameter of 2.54 cm (1 in.) provides a desirable, snug fit around the spaller bit.

■ System Operation

Setup

Setup time for the system under normal operation conditions is approximately 5 minutes. Before initiating the decontamination, the setup involves the following steps:

- Assemble the hoses to the hydraulic cylinder (if they have been removed)
- Check power cable and hoses for cuts or external wear
- Check vacuum port and exhaust system (if used) and connect all hoses
- Connect the power cord(s) to 110-volt source
- Perform a system check to verify that all of the components are operating
- Obtain water sprayer if used while pre-drilling holes.

Operation

Decontamination currently must be performed by two people. However, the system can be easily modified by replacing the manual four-way valve on the pump with an electrically operated valve, controlled from the spaller handle so spalling could be performed by one person. This is a PNNL-approved modification; it would be cost effective and practical.

In practice, the concrete wall to be decontaminated is first drilled with a pattern of the pilot holes on 20-cm (8-in.) centers. This process takes more time than the actual spalling. Depending upon the type of drill employed, each hole takes from 10 to 40 seconds to drill. Under Environmental Restoration practices at the Hanford Site, a water spray is used to control dust emissions when drilling concrete that is beta/gamma-contaminated. The spaller shroud has a vacuum hose fitting for connection to a HEPA filtration system if alpha contamination is present.

After a number of holes have been drilled, the spaller is inserted into the first hole and activated. Upon operating the four-way valve, the spalling bit expands almost immediately and spalling occurs, with a chunk of concrete falling into a metal shroud attached around the spaller. The worker proceeds to the next hole. Because of variations in the width of each spall, after completing an area of 1 to 5 m^2, a few additional holes and spalls may be needed to decontaminate 100% of the area.

SECTION 3

PERFORMANCE

■ Demonstration Overview/Plan

Site Description

The demonstration was conducted at DOE's Hanford Site by Bechtel Hanford, Inc. (BHI), the DOE's Environmental Restoration Contractor responsible for the D&D program at Hanford. The purpose of the LSDDP is to demonstrate new, commercially available and recently developed technologies during DOE D&D operations. In the case of C Reactor, the cost and performance of improved technologies are comprehensively assessed while placing the reactor block into an interim storage mode for up to 75 years, or until final disposal of the reactor's core is completed. The C Reactor ISS objectives include reducing or holding constant future decommissioning costs, minimizing releases to the environment, and reducing the frequency of inspections and potential risk to workers.

The DOE is in the process of D&D for many of its nuclear facilities throughout the country. Facilities have to be dismantled, and demolition waste must be sized into manageable pieces for handling and disposal. Typically, the facilities undergoing D&D are contaminated, either chemically, radiologically, or both. In its D&D work, the DOE was in need of a tool capable of removing surfaces of contaminated concrete floor and walls up to 3 mm (1/8 in.) in depth. The tool had to be easy and economical to operate, capable of operating in ambient temperatures from 3 to 40°C, and easy to decontaminate using conventional equipment. Use of the tool also had to be safe for workers. The spaller satisfies these needs and is an attractive alternative to traditional technologies such concrete scalers or single-piston scabblers used for similar operations.

The demonstrations of the concrete spaller and the baseline technologies were conducted in various sample rooms and a fan room in the C Reactor facility. Wall surfaces were decontaminated by using the spaller to remove at least 3 mm (1/8 in.) depth from the concrete surface.

Performance Objectives

Objectives of the demonstration included the following desired capabilities and design features of the equipment:

- Capable of removing concrete using a hand-held device weighing less than 14 kg (30 lb)
- Assembled with a dust collection shroud that has a fitting to attach to a HEPA filtration system
- Usable with commonly available utilities
- Able to work around steel reinforcing bar and piping that may be imbedded in the contaminated concrete
- Capable of readily removing concrete to a greater depth than with other commonly used hand-held tools.

Demonstration Chronology and Specific Technology Demonstration Instructions

The demonstration of the spaller described in Section 2 was conducted during January 1998 at two locations on an exhaust fan room wall in the Hanford Site C Reactor building. These wall areas had been surveyed previously, and beta/gamma contamination was well above release levels. Two portions of the wall that were beta/gamma-contaminated were drilled (using water spray for dust control) and spalled. A radiological control technician surveyed the wall areas that had been spalled to ensure that contamination was below release levels. The spalled chunks of concrete were left on the floor slab and later disposed of as low-level debris. Demonstration of the prototype spaller required two operators -- one operator to hold the unit and one operator to control the hydraulic valve at the pump. However, automatic valves could be added to allow single-operator application.

Technology Demonstration Results

Successes

- The spaller removed concrete surfaces to the depth desired and at greater depths at faster production rates than two traditional baseline tools and almost as fast as a newly adopted diamond grinder.
- The spaller did not cause significant emissions of nuisance dust, except for the predrilling step.
- The spaller vibrates much less than the baseline tools, is quiet in operation, and does not require the use of hearing protection.

Shortfalls

- The electric drill used for this demonstration was two to three times slower than a pneumatic drill that was used previously for spaller testing at an uncontaminated wall.
- The spaller weighs more than the baseline tools, causing worker fatigue, and was not supported by a sling, as was done for previous spaller testing at an uncontaminated wall.

Baseline Technology

The baseline demonstration was conducted on October 7, 1997, through November 3, 1997, on the interior C Reactor Sample Rooms A and B. Both sample rooms required 1.5 mm to 3 mm (1/16 in. to 1/8 in.) of concrete removal from floors and walls and for small areas to 6 mm (1/4 in.). Both sample rooms were painted with lead-based paint on the floor only.

The baseline decontamination tools demonstrated were a pneumatic scaler and scabbler, connected to a vacuum filtration system. In addition, an Innovative Technology Demonstration conducted later with a hand-held diamond grinder was successful, and the diamond grinder is now in the tool box for use at C Reactor, and at other facilities at Hanford, including F and DR reactors.

The scaler was designed to remove concrete surfaces between 1.5 mm to 6 mm (1/16 in. and 1/4 in.) depths. It contains a flapper device used to strike concrete surfaces. This tool is also useful in hard-to-reach horizontal areas, such as under equipment. The scaler has a port for connecting to vacuum filtration system. The other pneumatic baseline tool demonstrated was a scabbler designed to remove concrete surfaces between 3-mm and 6-mm (1/8-in. and 1/4-in.) depths. The single-piston hand-held scabbler can process moderately congested areas and operate near wall/floor intersections. This scabbler uses vacuum flow design for low dust operations (using HEPA suction at the striking point).

The diamond grinder was successfully demonstrated on November 12 and December 1, 1997. The grinder has a shroud with a port that was connected to a vacuum filtration system. The grinder is capable of removing 3 mm (1/8 in.) of material at a rate of 2.4 m^2/hr (24 ft^2/hr). The concrete grinder leaves a smooth surface that can be surveyed for contamination easily, and can remove concrete to depths of approximately 3 mm (1/8 in.) at a higher rate than the spaller. Details of the grinder performance are given in the Innovative Technology Summary Report, *Concrete Grinder* (OST Reference No. 2102).

COMPARISION OF IMPROVED TECHNOLOGY TO BASELINE

Table 1 summarizes the performance and operation of the improved technology compared to the baseline scabbler and scaler.

Table 1. Comparison to baseline performance

Parameter	Baseline		Improved
	Single-Piston Scabbler	Scaler	Concrete Spaller
Weight of Tool	22.7 kg (50 lb)	3 kg (6.5 lb)	<13.6 kg (30 lb)
Area Removed	12.2 m^2 (132 ft^2)	5.5 m^2 (59 ft^2)	4.6 m^2 (50 ft^2)
Depth Removed	3 mm (1/8 in.)	3 mm (1/8 in.)	50 mm to 3 mm (2 in. to 1/8 in.)
Production rate at 3 mm (1/8 in.) depth	1.11 m^2/hr (0.20 ft^2/min)	1.10 m^2/hr (0.197 ft^2/min)	1.3 m^2/hr (0.23 ft^2/min)

The improved technology removes material to a greater depth than the baseline tools; however, the spaller leaves the roughest finish and the largest volume of waste. Surface finish is not a concern for a structure about to be demolished.

Because of the variety of functions and facilities, the DOE complex presents a wide range of D&D working conditions. The working conditions for an individual job directly affect the manner in which D&D work is performed. The improved and baseline technologies presented in this report are based upon a specific set of conditions or work practices found at the Hanford Site (see Table 2). Table 2 is intended to help the technology user identify differences among the baseline scabbler and scaler tools and the spaller.

Table 2. Summary of variable conditions

Variable	Improved Technology	Baseline Technology
Scope of Work		
Quantity & types of material decontaminated in test areas	4.6 m^2 (50 ft^2) of a wall surface decontaminated.	12.3 m^2 (132 ft^2) floor and wall surfaces decontaminated with a scabbler and 5.5 m^2 (59 ft^2) with a scaler in two rooms.
Location of test area	Reactor Building Exhaust Fan Room.	Reactor Building, Sample Rooms A and B.
Nature of work	Surfaces were concrete.	Surfaces were concrete.
Work Environment		
Fixed or removable contamination in the test areas	Contamination present is fixed.	Contamination present is fixed.
Access within areas being decontaminated	Unobstructed.	Unobstructed.
Work Performance		
Technology acquisition means	Purchased tool.	Purchased tools.
Compliance requirements	Must meet Appendix D, 10 CFR 835 (see Attachment 1 to Procedure 2.3.3 in BHI-SH-02, Vol. 2, *Safety and Health Procedures*, "Unconditional Surface Contamination Release.")	Must meet Appendix D, 10 CFR 835 (see Attachment 1 to Procedure 2.3.3 in BHI-SH-02, Vol. 2, *Safety and Health Procedures*, "Unconditional Surface Contamination Release.")

Table 2. Summary of variable conditions (continued)

Variable	Improved Technology	Baseline Technology
Work Process Steps		
Operation	Plug in cord to electrical power supply. Inspect spalling bit occasionally, lubricate with molybdenum sulfide every 4th spall, and change the bit after 400 holes.	Attach vacuum hose to filtration unit and pneumatic hose to air compressor. Inspect scabbler head or scaler flappers occasionally during intermittent use, and change as necessary.

Meeting Performance Objectives

The objectives listed in the Demonstration Overview section were met, except the objective regarding the ability to work around imbedded steel was not demonstrated at C Reactor, because steel was not encountered. However, previous testing of the spaller indicated that the spaller functions adequately around imbedded steel.

Skills/Training

The skills and training required for field technicians are minimal, provided that the trainees are familiar with the use of similar equipment.

Operational Concerns

While the baseline tools must be used with a vacuum filtration unit and the workers must be vigilant to ensure that the vacuum hose stays connected properly and that a suitable level of vacuum is maintained, the spaller can be used without a vacuum system where no alpha contamination is a concern. The spaller uses high-pressure hydraulic oil, which could present a hazard if the spaller is held by the hydraulic fittings while it is being used. This is a natural grip, if no handle extension is provided on the tool. A handle extension was easily fabricated from stainless-steel pipe; a lighter version could be made from aluminum or plastic.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

■ Technology Applicability

- This technology can be used to decontaminate floors, walls, and other concrete structures.
- The system may be used both on interior and exterior concrete surfaces.
- The spaller would be the tool of choice for decontaminating cracks deeper than 3 mm (1/8 in.).
- The spaller can also be used to take concrete samples.

■ Competing Technologies

- Alternative tools to the spaller are the hand-held concrete diamond grinder and the other hand-held baseline tools (scaler and scabbler) assessed. The diamond grinder, also demonstrated at the Hanford Site C Reactor, has a comparable production rate, costs less to purchase, and is much lighter. The diamond grinder leaves a smooth surface, making post-decontamination surveys more reliable. However, this grinder is much slower than the spaller in situations where deep material removal is required (i.e., at a depth of more than 3 mm [1/8 in.]).
- Larger, push-type, wheel-powered and track-mounted decontamination devices are not comparable and are suitable for wide, open surfaces only. The hand-held tools demonstrated augment the larger devices. Other methods of concrete surface decontamination, such as laser ablation, media blasting, cryogenic nitrogen blasting, and carbon dioxide pellet blasting, take longer to set up and demobilize, cost more, and may not have as high of a production rate as the spaller.

■ Patents/Commercialization/Sponsors

- The spaller is in the prototype stage; the bit and some of the other components are not commercially available at this time. However, these parts can be produced in any well-equipped machine shop, using PNNL detailed drawings. The hydraulic pump and cylinder are commercially available, and both have been in production for at least 15 years.
- The spaller has been patented by PNNL.

SECTION 5

COST

Methodology

This section provides a cost-effectiveness analysis that compares the costs for the spaller to the baseline scabbler and scaler that were used to decontaminate walls at the Hanford Site C Reactor. This analysis determined the improved technology is 22% more expensive than the baseline for the conditions of this demonstration (inexperienced crew and inadequate drill), but the spaller is projected to save 15% compared to the baseline scabbler or scaler for optimum spalling conditions. This cost comparison for optimum spaller conditions is based on the tables in Appendix B, which account for mobilization, non-productive worker time, etc., as well as drilling and spalling time.

The cost analysis assumes site ownership of the equipment and site labor. The cost-effectiveness estimate is based on decontamination of 12.3 m^2 (132 ft^2) of wall. The baseline costs are from direct observation of wall decontamination using a single-piston scabbler and a scaler. The improved costs use production rates determined from the demonstration. The observed spaller production rates were used to extrapolate the costs to 12.3 m^2 (132 ft^2) to match the baseline scabbler quantity of work and this cost is reported as the "as-demonstrated" costs. Previous work (references No. 10 and No. 11) provides production rate information for larger jobs and for experienced crews. The costs based on production rates for the previous work are included in this analysis as the "optimum conditions" costs. The cost-effectiveness analysis includes setting the spaller up in the work area, sleeving hydraulic or air compressor hoses with plastic sheeting, removing concrete wall surface, demobilizing from the work area, and disposing of waste.

Cost Analysis

The spaller technology uses some components that are commercially available (hydraulic pump and cylinder and the impact drill), but the spalling wedge tool (bit with push rod) is not commercially available. The spalling wedge was fabricated from parts that were machined on site. The machined parts were heat-treated at another location. The hydraulic cylinder costs $602. The raw materials for machining were $110. Machining and heat treating for bit wedges, push rods, and aluminum fittings cost $3,373. Sheet metal and fabrication for the shroud cost $878. The labor cost for assembly of the unit is $50. Total cost is approximately $5,000. The replacement cost for the wedges is $2,000 for machining five wedges. The hydraulic pump used in the demonstration has a purchase price of $2,079; the electric rotary hammer costs $578; and drill bits cost $44 each. The wedge and drill bits are expected (based on previous work described in reference No. 10) to have a service life of 400 spalls and 400 holes each, respectively. Other than routine lubrication, the principal maintenance costs are associated with the hydraulic power unit and include annual changing of the hydraulic fluid.

Observed unit costs and production rates for principal components of the demonstrations for both the improved and baseline technologies are presented in Table 3:

Table 3. Summary of production rates and unit costs for minimum of 3 mm depth removal

	Improved				Baseline - Scaler				Baseline - Scabbler			
	Production Rate		Unit Cost		Production Rate		Unit Cost		Production Rate		Unit Cost	
Cost Element	m^2/hr	(ft^2/hr)	\$/m^2	(\$/ft^2)	m^2/hr	(ft^2/hr)	\$/m^2	(\$/ft^2)	m^2/hr	(ft^2/hr)	\$/m^2	(\$/ft^2)
Drill Holes					N/A		N/A		N/A		N/A	
• As Demonstrated	1.15	(12.34)	142	(13.16)								
• Optimum Conditions	1.64	(17.6)	99	(9.22)								
Decontaminate Wall												
• As Demonstrated	2.76	(30.0)	58	(5.41)	1.10	(11.8)	155	(14.4)	1.11	(12)	156	(14.5)
• Optimum Conditions	5.57	(60.0)	29	(2.71)	N/A		N/A		N/A		N/A	
Total Unit Costs												
• As Demonstrated			200	(18.52)			155	(14.4)			156	(14.5)
• Optimum Conditions			128	(11.93)								

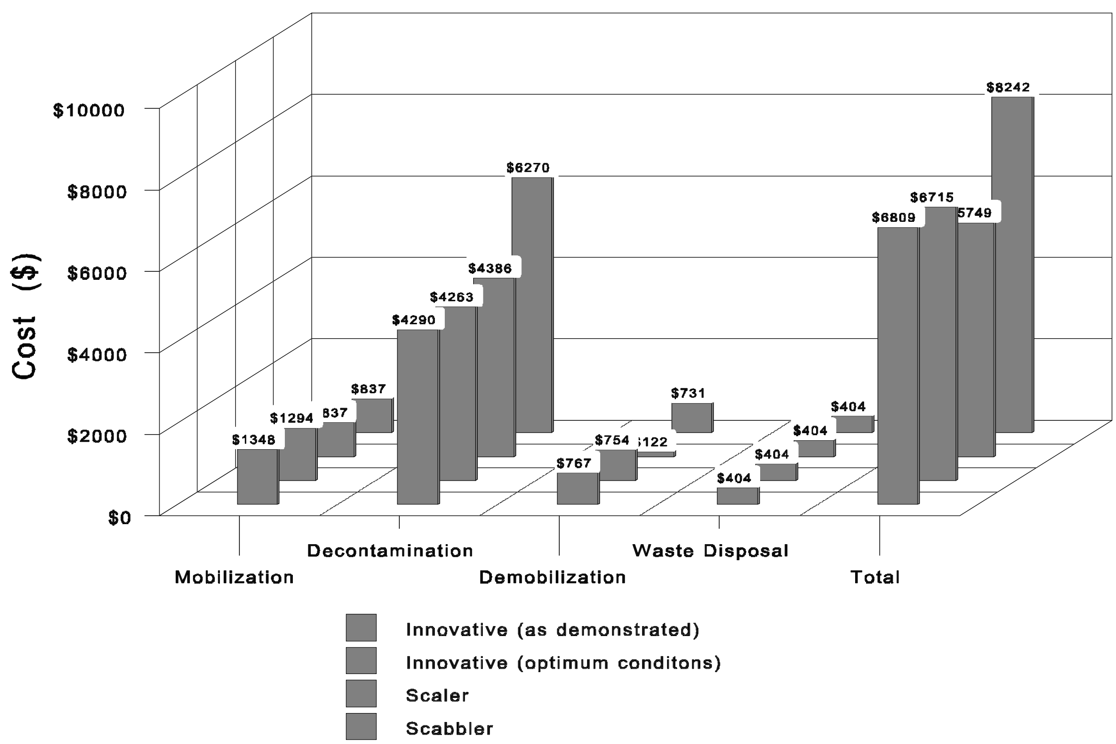
The unit costs and production rates shown do not include mobilization or other losses associated with non-productive portions of the work (e.g., suit-up, breaks, or replacing bits). Table 3 is intended to show unit costs at their elemental level that are free of site-specific factors (e.g., work culture or work environment influences on productivity loss factors). Consequently, the unit costs shown in Table 3 are the same unit costs for the corresponding line item in Tables B-2, B-3, and B-4 of Appendix B. Tables B-2, B-3, and B-4 can be used to compute site-specific costs by inserting quantities and adjusting the units for conditions of an individual D&D job.

Some features of the demonstration that affect cost are unique to the Hanford Site and to this demonstration. Consequently, the specific conditions at other sites will result in different costs. The following site-specific conditions for this demonstration are judged to be the principal factors affecting costs:

- An electric rotary hammer drill was used rather than a pneumatic drill that would have been faster.
- Work area assumed is a radiological contamination area and an airborne radiological area.
- Disposal cost for waste is $60/ton (not a major factor in cost analysis for the Hanford Site).
- One worker was stationed outside the contaminated area for the duration of the work.

COST COMPARISON

The improved technology has been separated into two scenarios so the sensitivity of the costs is apparent. The first scenario is based on the observed production rates for drilling and for spalling. The second (optimum conditions) scenario is based on the production rates reported for previous testing. Using previous production rates is appropriate because the drill available for the demonstration was slower than what would be used for deployment. Refer to Appendix B of this report for detailed cost tables for the spaller cost with the optimum conditions scenario and for the two baseline totals. The costs for the two spaller scenarios and the two baseline tools are summarized in Figure 6.



■ Cost Conclusions

The major cost drivers for the improved technology are donning and doffing personal protective equipment (PPE) and the PPE costs, drilling holes, and lost time. The baseline has the same cost drivers, as well as the wall decontamination.

The production rates for drilling may vary over a wide range. The initial observed production rate was six holes in 10 minutes (100 seconds/hole). The relatively low productivity is assumed to be the result of inexperience and a small initial quantity of wall treatment. Subsequent drilling during the demonstration indicated that drilling holes with the electric rotary hammer will provide production rates of a hole every 34 seconds. Previous work (reference No. 10) indicated a drilling production rate of a hole every 40 seconds with an electric rotary hammer. Additionally, previous work indicated that pneumatic drills have production rates of approximately one hole every 10 seconds. There is a potential for great increases of production rate for the spaller technology by using a pneumatic drill, but that advantage would be offset to some degree by higher equipment costs (costs that include an air compressor). The optimum conditions scenario in this cost analysis assumed 40 seconds drilling time for each hole with an electric rotary hammer plus 30 seconds to set up for the next hole.

The production rates for spalling vary widely: 2.8 m^2/hr (30 ft^2/hr) observed; and 5.6 m^2/hr (60 ft^2/hr) based on use of an electric rotary hammer and other typical D&D work practices. However, the potential variation has only a small impact on the total cost because the spalling is a relatively small component in the total cost.

The observed production rate for the scaler varied over a range of 0.5 m^2/hr (5.7 ft^2/hr) to 1.7 m^2/hr (18 ft^2/hr) depending upon the specific conditions of the work. The estimate is based on 1.10 m^2/hr (11.8 ft^2/hr). A substantial variation from the production rate used in this cost analysis is possible (depending upon conditions present at other work locations) and could possibly change the conclusions of the cost comparison.

The time lost from productive work due to resolving issues, waiting on radiological control technicians, and dealing with unexpected conditions was the largest single cost. This analysis assumes almost 3 hours lost for each day worked for both the baseline and the improved technologies based on previous deployments in areas designated as radiation area and airborne contamination area. Lost time is a site-specific factor that is anticipated to vary over a wide range.

The tables in Appendix B allow the reader to make an estimate for their site by inserting their site's quantities into the cost estimate tables.

SECTION 6

REGULATORY AND POLICY ISSUES

■ Regulatory Considerations

- The spaller is a surface decontamination tool used on concrete. No special regulatory permits are required for its operation and use.

- This system can be used in daily operation under the requirements of 10 CFR, Parts 20, 835, and proposed 834 for protection of workers and the environment from radiological contaminants and 29 CFR 1910 and 1926, Occupational Safety and Health Administration (OSHA) worker requirements.

- Although the demonstration took place at a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) site, no CERCLA requirements apply to the technology demonstrated.

■ Safety, Risk, Benefits, and Community Relations

Worker Safety

- BHI-SH-04, *Radiological Control Work Procedures,* apply to this work. Respiratory protection should be included where alpha contamination may be of concern.

- In conditions of potential airborne contamination, a vacuum filtration system and respiratory protection must be employed while spalling. If a vacuum filtration system is used, the operator must be vigilant that the vacuum hose connections remain secured, that adequate vacuum is maintained, and that the filters are operating normally to avoid spreading contamination.

- Procedures and equipment must meet the National Electrical Code standards.

Community Safety, Environmental and Socioeconomic Impacts, and Community Perception

Implementation of the concrete spalling technology would not present any adverse impacts to community safety or the environment if vacuum filtration is used. No socioeconomic impacts are expected from the use of this technology.

SECTION 7

LESSONS LEARNED

■ Implementation Considerations

No special implementation concerns apply to concrete spaller technology. A 110-V electrical power supply voltage and circuitry are used for the hydraulic pump. A HEPA vacuum filtration unit should be used with the spaller if alpha contamination is present.

■ Technology Limitations/Needs for Future Development

- Lubrication of the sliding surfaces of the spalling bit is required every four spalls for best performance and bit life. A long-lasting lubricant and/or an automatic lubrication device would make spaller operation more convenient.
- Fabrication of the spalling bit is fairly difficult, particularly machining the taper of the push rod within the bit. A simplified design, or some other manufacturing technique, would reduce the cost of this expendable part.
- Because of variations in the width of each spall, after completing an area of 1 to 5 m^2, a few additional holes and spalls may be needed to decontaminate 100% of the area.
- Currently there is no need to modify the tool as demonstrated at the Hanford Site C Reactor. A lighter handle and/or a longer extension would make the tool easier to use and reduce operator fatigue.
- The electric drill used for this demonstration was two to three times slower than a pneumatic drill that was used previously for spaller testing at an uncontaminated wall.
- The spaller weighs more than the baseline tools, causing worker fatigue, and was not supported by a sling as was done for previous spaller testing at an uncontaminated wall.
- In the early 1980s, a similar tool was tested on an uncontaminated wall, using automated drilling and spalling rigs. Given the advances in robotic technology over the last 18 years, an automated system should be tested/demonstrated again when a large surface requires decontamination.
- The demonstration required a second worker to manually apply water while the pilot holes were drilled into the contaminated wall. The drill could be fitted with an automatic water spray nozzle or a vacuum shroud (connected to a HEPA filtration system), enabling one worker to safely perform the drilling.
- Demonstration of the prototype spaller required two operators: one operator to hold the unit and one operator to control the hydraulic valve. However, automatic valves could be added to allow single-operator application.

■ Technology Selection Considerations

- The technology is suitable for DOE nuclear facility D&D sites or similar sites where concrete structures must be decontaminated or sampled to facilitate property transfer or release. The concrete spaller is applicable for removing both radioactive contamination and hazardous substances.
- The technology demonstrated is suitable for shallow contamination but particularly effective when contamination exists more than 1.3 cm (½ in.) under the surface of the concrete. That is, the improved technology removes material to a greater depth than the baseline tools; however, the spaller leaves the roughest finish and the largest volume of waste. Surface finish is not a concern for a structure about to be demolished.
- The spaller has good potential for removing contamination where there are cracks, crevices, or joints in concrete.

- The hand-held light-weight tool demonstrated should be considered where obstructions or structural geometry make larger concrete ablation devices impractical and where a smooth finish is not necessary.

APPENDIX A

REFERENCES

1. 10 CFR Part 20, "Standard for Protection Against Radiation," *Code of Federal Regulations,* as amended.

2. 10 CFR Part 834, "Environmental Radiation Protection," *Code of Federal Regulations,* as amended.

3. 10 CFR Part 835, "Occupational Radiation Protections," *Code of Federal Regulations,* as amended.

4. 29 CFR Part 1910, "Occupational Safety and Health Standards," *Code of Federal Regulations,* as amended.

5. 29 CFR Part 1926, "Safety and Health Regulations for Construction," *Code of Federal Regulations,* as amended.

6. BHI-SH-02, *Radiological Control Work Procedures*, Procedure 2.3.3, Attachment 1, Bechtel Hanford, Inc., Richland, Washington.

7. *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), 42 U.S.C. 9601, et seq.

8. Innovative Technology Summary Report, *Concrete Grinder,* OST Reference No. 2102, June 1998.

9. OMB, *Cost Effectiveness Analysis*, OMB Circular No. A-94, Office of Management and Budget, Washington, D.C.

10. PNL, 1982, PNL-4029, *Surface Concrete Decontamination Equipment Developed by Pacific Northwest Laboratory*, Pacific Northwest Laboratory, Richland, Washington.

11. PNL, 1989, *324 And 325 Building Hot Cell Clean out Program Air Lock Cover Block Refurbishment,* PNL-6898, Pacific Northwest Laboratory, Richland, Washington.

12. R.S. Means Co., 1997, *Means Construction Equipment Cost Data*, R.S. Means Co., Kingston, Massachusetts.

13. USACE, 1996, *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*, Headquarters, U.S. Army Corps of Engineers, Washington, D.C.

APPENDIX B

COST COMPARISON

Introduction

The cost-effectiveness analysis computes the cost for a concrete wall decontamination job by using hourly rates for equipment and labor.

The selected basic activities being analyzed come from the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS) (USACE 1996). The HTRW RA WBS, developed by an interagency group, used in this analysis to provide consistency with the established national standards.

Some costs are omitted from this analysis for ease of understanding and facilitating comparison with costs for the individual site. The overhead and general and administrative (G&A) markup costs for the site contractor managing the demonstration are omitted from this analysis. Overhead and G&A rates for each DOE site vary in magnitude and in the way they are applied. Decision makers seeking site-specific costs can apply their site's rates to this analysis without having to first back-out the rates used at the Hanford Site.

The following assumptions were used as the basis of the improved cost analysis:

- Oversight engineering, quality assurance, and administrative costs for the demonstration are not included. These are normally covered by another cost element, generally as an undistributed cost.

- The procurement cost of 7.5% was applied to all purchased equipment costs so that the costs of administering the purchase are accounted for (this cost is included in the hourly rate).

- The equipment hourly rates for the improved technology, Government's ownership option, are based on general guidance contained in Office of Management and Budget (OMB) Circular No. A-94, *Cost Effectiveness Analysis.*

- The equipment hourly rates for the site-owned equipment that may be used in support of the improved equipment (e.g., the site-owned truck that transports the rented improved equipment from the warehouse receiving to the C Reactor) uses standard equipment rates established at the Hanford Site.

- The standard labor rates established by the Hanford Site for estimating D&D work are used in this analysis for the portions of the work performed by local crafts.

- The analysis uses a 10-hour work day.

- An anticipated life of 10, 5, and 3 years, respectively, for the spaller, hydraulic power unit, and the electric rotary hammer (based on PNNL's engineering judgment) and an average usage of 500 hours/year are used in the calculation of hourly rate for the improved technology.

MOBILIZATION (WBS 331.01)

Move Tools to Work Area: The observed time required for retrieving the grinder and other small tools for the baseline from storage and moving them to the work area was used for the improved technology.

Move/Setup VAC-PAC: This activity applies only to the baseline and is based on observed duration.

Sleeve Hoses & Prepare Equipment: Both the improved and the baseline tools have equipment stationed outside the contamination area that connect to/feed the tools used in the contamination area. The spaller uses a hydraulic power unit, and the baseline tools use a vacuum filtration unit. The duration for this activity is based on the observed time required for the baseline.

DECONTAMINATION (WBS 331.17)

Safety Meeting: The baseline work required a safety meeting each morning following the first day of work. The costs for the improved were assumed to be similar to the observed duration for the baseline.

Don and Doff PPE: This cost item includes time for each worker to fully suit-up in PPE as well as material costs for the PPE, and includes removal of the PPE. The time spent donning and doffing each day is based on observed times for previous deployments (long-term and large-scale jobs). Material costs for daily PPE for one D&D worker at the Hanford Site are shown in the table below:

Equipment	Cost Each Time Used ($)	No. Used Per Day	Cost Per Day ($)
Air purifying respirator (PAPR)	71.06	1 ea	71.06
Face shield	1.28	1 ea	1.28
Booties	0.62	2 pr	1.24
Coverall	5.00	2 ea	10.00
Double coverall (5% of the time)			0.56
Hood	2.00	2 ea	4.00
Gloves (inner)	0.14	2 pr	0.28
Gloves (outer)	1.30	2 pr	2.60
Gloves (liner)	0.29	2 pr	0.58
Rubber overshoe	1.38	2 pr	2.76
Total			**94.36**

Notes: Based on a PAPR price of $603/each, assuming 50 uses; four cartridges required per day at a cost of $14/each; and maintenance and inspection costs of $150 over the life of the PAPR (50 uses). One worker is assumed to remain outside the contaminated area and is not suited up. Based on a face shield price of $64/each and assuming 50 uses.

Drill Holes for Spaller: During the demonstration, six holes were drilled initially in approximately 10 minutes, indicating a production rate of 36 holes/hr or 1.1 m^2/hr (12.3 ft^2/hr). Previous work (reference No. 10) suggests that the time required to drill one hole using an electric rotary hammer is 40 seconds; using an air-powered rotary hammer takes less than 10 seconds. This estimate is based on a drill time of 40 seconds plus 30 seconds to set up at the next hole (total of 1.17 minutes). The production rate used is 1.6 m^2/hr (17.6 ft^2/hr) as representing a conservative optimum rate.

Replace Drill Bits for Spaller: Drill bits are assumed (not based on observed) to have a service life of 400 holes. The time associated with stopping work, removing the old drill bit, finding a new drill bit, and replacing the bit is assumed to be 15 minutes. The 15 minutes would be averaged over 400 holes, or approximately 13 m^2 (140 ft^2). The price for a 2.54-cm (1-in.)-diameter drill bit (to fit a Hilti™ rotary hammer drill) is $46.96 (McMaster-CARR catalog price). Averaging the bit price over 13 m^2(140 ft^2.) is $0.03/m^2 ($0.334/ft^2).

Spall Concrete Wall: The observed production rate in the demonstration was approximately 10 minutes to spall 19 holes plus approximately 3 minutes to perform rad surveys. This is equivalent to an observed production rate of 88 spalls/hr or 2.8 m^2/hr (30 ft^2/hr). Previous work (reference No. 10) suggests that the spaller production rate can be 5.6 m^2/hr (60-ft^2/hr) with an experienced crew and large wall area. The production rate used in this estimate is the latter as representing the optimum rate.

Replace Spaller Wedge: The estimated cost (from engineer Mark Mitchell of PNNL) for making five wedges is approximately $2,000. A wedge is expected to last 400 spalls. The cost of $400/wedge averaged over 400 spalls or 13 m^2 (140 ft^2) is $0.27/m^2 ($2.86/ft^2). The time associated with stopping work, removing the old wedge, finding a replacement, and replacing the wedge is assumed to be 15 minutes. The 15 minutes would be averaged over 400 spalls or 13 m^2 (140 ft^2). Average time lost to replacement of spaller wedges per square meter is 65 seconds (per square foot is 6.1 seconds).

™Hilti is a registered trademark of Hitti Corporation, Tulsa, Oklahoma.

Cleanup Spalls: Unlike the baseline, the improved will automatically vacuum the debris generated during the work. This cost analysis assumes 30 minutes to collect the spalls (not an observed activity).

Remove Concrete Wall Surface Down 1.5 mm (1/16 in.) with the Scaler (Rooms A & B): Concrete removal was conducted with a crew consisting of three D&D workers. Two of the workers were fully suited in PPE (equipped with respirators) and worked inside the contamination area. The other worker acted as a "runner," supporting the workers inside the contamination area by providing them with needed supplies and ensuring the air and vacuum lines remained operational. Removal work took place in different rooms at the C Reactor rooms A and B on 5.5 m^2 (59 ft^2) of wall surface and room X for 4 m^2 (42 ft^2). For the cost analysis, the area of removal is extrapolated to the area of wall surface removed with the scabbler, or 132 ft^2. Based on the type of contamination, it was only necessary to remove the concrete to 1.5 mm (1/16 in.) depth. The production rate for room "X" of 1.7 m^2/hr (18 ft^2/hr) was averaged with the production rate for rooms A and B of 0.5 m^2/hr (5.73 ft^2/hr) for an overall average of 1.1 m^2/hr (11.8 ft^2/hr).

Remove Concrete Wall Surface Down 1.5 mm (1/16 in.) with the Scabbler: As with the scaler, concrete removal was conducted with a crew of three D&D workers. Removal also took place in demonstration rooms A and B at the C Reactor, but on 12.3 m^2 (132 ft^2) of wall surface. (As noted for the improved technology and other baseline technologies, this area of removal forms the basis of comparison for all three technologies). It was also necessary to remove the concrete wall surface to only 1.5 mm (1/16 in.) depth with this technology; but, because of limitations of the technology, the device removed material in a range of 1.5 to 3 mm (1/16 to 1/8 in.) depth. Removal time includes the time it took to move the scabbler from spot to spot within each of rooms A and B.

Scaler Carbide Flap Replacement: Carbide flaps cost $4.53/hr when the scaler is in use. This is equivalent to a cost of $0.035/$m^2$ ($0.38/$ft^2$) for production rates of 1.1 m^2/hr (11.8 ft^2/hr).

Scabbler Bit Replacement: Scabbler bits cost $1.53/hr when the scabbler is in use. This is equivalent to a cost of $0.012/$m^2$ ($0.13/$ft^2$) for production rates of 1.1 m^2/hr (12 ft^2/hr).

Non Productive Time: The nonproductive time used in this cost analysis for both the improved and the baseline is based on observed lost time for previous deployments (long-term jobs of large size). An average loss per day of 3 hours is used to account for unexpected issues with the work, waiting on radiological control technician support, etc.

Wrap PAPRs: The average time observed in the baseline for wrapping powered air-purifying respirators (PAPRs) was assumed for both the improved and the baseline.

DEMOBILIZATION (WBS 331.21)

Disassemble & Decontaminate Equipment: The durations observed for each of the improved and the baseline demonstrations are used in their respective cost estimates.

WASTE DISPOSAL (WBS 331.18)

Disposal of PPE, Plastic, Sheeting, and Sleeving: The observed quantity and duration for the baseline is assumed for the improved.

Disposal of Concrete: The quantities of waste are not known. However, the costs are assumed to be minimal (less than 1 ton of waste), and this analysis assumes a minimal charge based on $60/ton for disposal at the Environmental Restoration Disposal Facility.

The details of the cost analysis for the two improved options and the baseline are summarized in Tables B-1, B-2, and B-3.

Table B-1. Cost summary - improved technology at optimum production rates

Work Breakdown Structure (WBS)	Unit	Unit Cost $	Qty	Total Cost $	Computation of Unit Cost						Othe and C
					Prod. Rate	Duration (hr)	Labor & Equipment Rates				
							Labor Items	$/hr	Equipment Items	$/hr	
MOBILIZATION (WBS 331.01)		Subtotal		$837.21							
Move Tools to Work Area	ls	$ 555.69	1	$ 555.69		8.33	2DD	$63.94	SP+RD+HP+TK	$2.77	
Sleeve Hoses	ls	$ 281.51	1	$ 281.51		2.2	2DD	$19.20	SP+RD+HP	$8.76	
DECONTAMINATION (WBS 331.17)		Subtotal		$4,386.28							
Safety Meeting	day	$ 40.59	2	$ 81.17		0.25	3DD+1RCT	$145.41	SP+RD+HP+RS	$16.93	
Don and Doff Personal Protective Equipment (PPE)	day	$ 570.42	2	$ 1,140.84		1.77	same	$145.41	same	$16.93	PPE at $94.36/pe unit cost
Drill Holes	SF	$ 9.22	132	$ 1,217.55	17.6		same	$145.41	same	$16.93	17.6 ft^2/hr
Replace Drill Bits	SF	$ 0.61	132	$ 80.65		0.0017	same	$145.41	same	$16.93	10 min to change for every 140 ft^2
Spall Wall	SF	$ 2.71	132	$ 357.15	60		same	$145.41	same	$16.93	Production rate 6
Replace Spaller Wedge	SF	$ 3.14	132	$ 413.95		0.0017	same	$145.41	same	$16.93	
Cleanup Spalls	LS	$ 81.17	1	$ 81.17		0.5	same	$145.41	same	$16.93	
Lost Time	day	$ 482.15	2	$ 964.30		2.97	same	$145.41	same	$16.93	
Wrap PAPR's	day	$ 24.75	2	$ 49.50		.5	RCT	$ 49.50			
DEMOBILIZATION (WBS 331.21)		Subtotal		$121.91							
Disassemble & Decontaminate Equipment	LS	$121.91	1	$121.91		0.5	4DD+2RCT	$26.88	same	$16.93	
WASTE DISPOSAL (WBS 331.18)		Subtotal		$403.60							
Disposal of PPE, Plastic Sheeting, & Sleeving	LS	$116.72	1	$116.72		0.5	2DD+1RCT	$13.44		$0.00	Disposal fee of $
Disposal of Concrete	LS	$286.88	1	$286.88		2	2DD+1RCT	$13.44			Disposal fee of $
TOTAL				$5,748.99							

Crew Person	Rate $/hr	Abbrev.	Crew Person	Rate $/hr	Abbrev.	Item	Rate $/hr	Abbrev	Item	Ra $/h
Field Supervisor	59.60	SU	Rigger	43.57	RG	Truck Tractor	11.7	TT	Truck (flat bed)	4
D&D Worker	31.97	DD	Scientist	65.18	SC	Low Boy Trailer	0.48	LB	Trailer (flat bed)	0
Teamster	36.35	TM	Lead Sampling Technician	54.77	LT	Spaller	1.75	SP	Hydraulic Pump	1
Heavy Equipment Operator	38.68	OP	Radiological Control Technician	49.50	RCT	Rotary Hammer Drill	0.56	RD	Radiological Survey Equipment	1
						Air Compressor	6.74	AC	Cutting Torch	8

Notes:

1. Unit Cost = (Labor + Equipment Rate) x Duration + Other Cost, or
   (Labor + Equipment Rate) / Productivity Rate) + Other Cost
2. Abbreviations for units: LS = lump sum; SF = square feet

Table B-2. Cost summary - scabbler baseline technology

Structure	Unit	Unit Cost $	Qty	Total Cost $	Computation of Unit Cost						Other Costs
					Prod. Rate	Duration (hr)	Labor & Equipment Rates				
							Labor Items	$/hr	Equipment Items	$/hr	
(WBS 331.01)			Subtotal	$1,348.37							
rk Area	LS	$ 761.86	1	$ 761.86		8.33	2DD	$ 63.94	SP+VP+AC	$ 27.52	
PAC	LS	$ 385.30	1	$ 385.30		2	5DD	$ 159.85	same + TK+TR	$ 32.80	
	LS	$ 201.21	1	$ 201.21		2.2	2DD	$ 63.94	SP+VP+AC	$ 27.52	
TION (WBS 331.17)			Subtotal	$4,289.84							
	day	$ 43.58	2	$ 87.16		0.25	3DD+1RCT	$ 145.41	SP+VP+AC+RS	$ 29.90	
onal ent (PPE)	day	$ 591.61	2	$ 1,183.22		1.77	same	$ 145.41	same	$ 28.90	PPE at $94.36/ added to unit c
	SF	14.53	132	$ 1,917.41	12		same	$ 145.41	same	$ 28.90	Production rate
	SF	$ 0.13	132	$ 17.16			same	$ 145.41	same	$ 28.90	Includes $0.13
	day	$ 517.70	2	$ 1,035.40		2.97	same	$ 145.41	same	$ 28.90	
	day	$ 24.75	2	$ 49.50		.5	RCT	$ 49.50			
ON (WBS 331.21)			Subtotal	$767.34							
uipment	LS	$767.34	1	$767.34		3	4DD+2RCT	$26.88	same	$28.90	
AL (WBS 331.18)			Subtotal	$403.60							
lastic ng	LS	$116.72	1	$116.72		0.5	2DD+1RCT	$13.44		$0.00	Disposal fee of
te	LS	$286.88	1	$286.88		2	2DD+1RCT	$13.44			Disposal fee of
TOTAL				$6,809.16							

	Rate $/hr	Abbrev	Crew Person	Rate $/hr	Abbrev	Item	Rate $/hr	Abbrev	Item	Rat $/h
	59.60	SU	Rigger	43.57	RG	Truck Tractor	11.71	TT	Truck (flat bed)	4
	31.97	DD	Scientist	65.18	SC	Low Boy Trailer	0.48	LB	Trailer (flat bed)	0
	36.35	TM	Lead Sampling Technician	54.77	LT	Single Piston Scabbler	5.07	SP	Loader	23
	38.68	OP	Radiologic Control Technician	49.50	RCT	Vacuum Filtration Unit	15.71	VP	Radiological Survey Equipment	1
						Air Compressor	6.74	AC	Cutting Torch	8

: (Labor +Equipment Rate) x Duration + Other Cost, or
(Labor +Equipment Rate) / Productivity Rate) + Other Cost
bbreviations for units: LS = lump sum; SF=square feet

Table B-3. Cost summary - scaler baseline technology

lown Structure /BS)	Unit	Unit Cost $	Qty	Total Cost $	Computation of Unit Cost						
					Prod. Rate	Duration (hr)	Labor & Equipment Rates				Other Costs/a
							Labor Items	$/hr	Equipment Items	$/hr	
'ION (WBS 331.01)			**Subtotal**	$1,293.99							
Work Area	LS	$ 725.71	1	$ 725.71		8.33	2DD	$ 63.94	RP+VP+AC	$ 23.18	
'AC-PAC	LS	$ 376.62	1	$ 376.62		2	5DD	$ 59.85	same + TK+TR	$ 28.46	
	LS	$ 191.66	1	$ 191.66		2.2	2DD	$ 63.94	RP+VP+AC	$ 23.18	
IINATION (WBS 331.17)			**Subtotal**	$4,263.48							
;	day	$ 42.49	2	$ 84.99		0.25	3DD+1RCT	$145.41	RP+VP+AC+RS	$ 24.56	
Personal ipment (PPE)	day	$ 583.93	2	$ 1,167.85		1.77	same	$145.41	same	$ 24.56	PPE at $94.36/p added to unit co:
	SF	14.40	132	1,901.36	11.8		same	$145.41	same	$ 24.56	Production rate
placement	SF	$ 0.38	132	$ 50.16			same	$145.41	same	$ 24.56	Includes $0.38/f
	day	$ 504.81	2	$ 1,009.62		2.97	same	$145.41	same	$ 24.56	
	day	$ 24.75	2	$ 49.50		.5	RCT	$ 0.00			
:ATION (WBS 331.21)			**Subtotal**	$754.32							
: Equipment	LS	$754.32	1	$754.32		3	4DD+2RCT	$26.88	same	$24.56	
'OSAL (WBS 331.18)			**Subtotal**	$403.60							
'E, Plastic eeving	LS	$116.72	1	$116.72		0.5	2DD+1RCT	$13.44		$0.00	Disposal fee of $
oncrete	LS	$286.88	1	$286.88		2	2DD+1RCT	$13.44			Disposal fee of $
TOTAL				$6,715.39							

son	Rate $/hr	Abbrev	Crew Person	Rate $/hr	Abbrev	Item	Rate $/hr	Abbrev	Item	Ra $/h
;or	59.60	SU	Rigger	43.57	RG	Truck Tractor	11.71	TT	Truck (flat bed)	4
	31.97	DD	Scientist	65.18	SC	Low Boy Trailer	0.48	LB	Trailer (flat bed)	(
	36.35	TM	Lead Sampling Technician	54.77	LT	Scaler	0.73	RP	Loader	23
nent	38.68	OP	Radiologic Control Technician	49.50	RCT	Vacuum Filtration Unit	15.71	VP	Radiological Survey Equipment	1
						Air Compressor	6.74	AC	Cutting Torch	8

Notes: 1. Unit Cost = (Labor +Equipment Rate) x Duration + Other Cost, or
(Labor +Equipment Rate) / Productivity Rate) + Other Cost

2. Abbreviations for Units: LS = lump sum; SF=square feet

APPENDIX C

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Description
ALARA	as low as reasonably achievable
BHI	Bechtel Hanford, Inc.
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
G&A	general and administrative (costs)
HEPA	high-efficiency particulate air (filtration)
HTRW	hazardous, toxic, radioactive waste
ISS	interim safe storage
LSDDP	Large-Scale Demonstration and Deployment Project
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
OST	Office of Science and Technology
PAPR	powered air-purifying respirator
PNNL	Pacific Northwest National Laboratory
PPE	personal protective equipment
RA	remedial action
USACE	U.S. Army Corps of Engineers
WBS	work breakdown structure

Note: Additional acronyms and abbreviations are defined in